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The Measurement of Systemic Blood Flow.* (19397)

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Various technics for the measurement of cardiac output or large portions thereof have been proposed by Gregg and Shipley(1), Wegria *et al.*(2,6), Seely and Gregg(3), Eckstein *et al.*(4), and Bohr and Henriques (5). The method to be described below measures systemic blood flow, *i.e.* cardiac output minus coronary flow. It is relatively simple to perform and has the virtue of being accomplished by cannulation only of intrathoracic vessels.

Recent work has shown the adaptability of the Potter turbinometer to the problems of measuring total aortic flow(7). This flowmeter records pulsating flow as accurately as steady flow, and thus the necessity for using a buffer bottle or pressure reservoir in the system has been eliminated along with the undesirable shift of blood from dog to bottle and vice versa that occurs with variations in arterial pressure. Further, the sensing element is a tube 2.5 inches x 0.5 inch and significantly decreases the amount of blood required to fill the system when compared to a system using a rotameter with a buffer bottle.

Method. Mongrel dogs of both sexes were anesthetized with morphine sulfate, 4 mg per kg intramuscularly, and chloralose, 48 mg per kg, and urethane, 480 mg per kg intravenously. Dogs in excess of 14 kg were used. Smaller dogs may be used if the cannulae are made of a size smaller than those listed in Fig. 1. After a tracheotomy cannula is inserted, positive pressure breathing is maintained with a modified Starling pump. With the dog on its right side, the left ribs 3, 4 and 5 are then partially removed. The first 3 sets of intercostal vessels are ligated, but the aorta is not dissected free in order to eliminate the ooze that might otherwise occur after heparinization. The brachycephalic artery is then cleared from its point of origin to its bifurca-

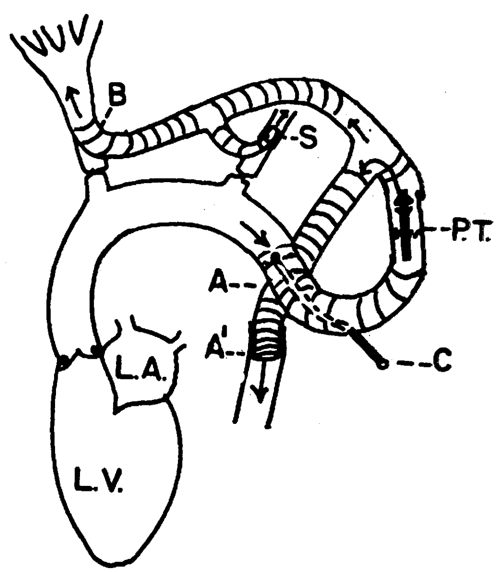

FIG. 1. Schema of aortic flow technic. See text. Desirable minimal internal diameters of cannulae are 10 mm for A, 9 mm for A', 8 mm for B, and 3 mm for S for use in dogs from 15 to 20 kg.

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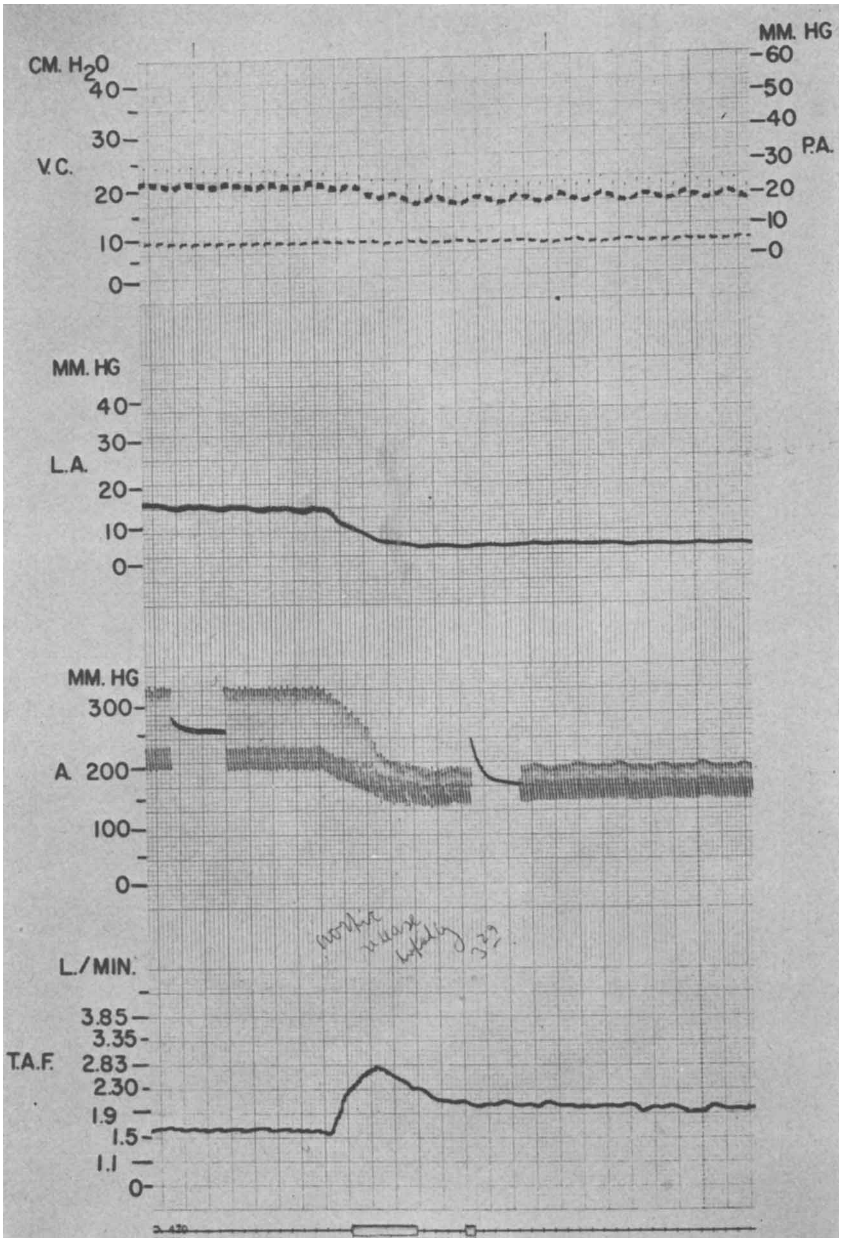

FIG. 2. T.A.F. = Total aortic flow (cardiac output minus coronary flow). A = Aortic pressure. L.A. = Left auricle pressure. V.C. = Vena cava pressure (lower tracing on top channel; scale at left). P.A. = Pulmonary artery pressure (upper tracing on top channel; scale at right). Time marker at bottom in seconds. Prior to beginning of tracing a screw clamp was placed on the tubing of outflow cannula A (Fig. 1) so as to increase aortic pressure and resistance and produce arterial hypotension distal to the screw clamp with consequent reflex vasoconstriction. Aortic clamp released at first signal. Heavy black lines = integrated (mean) pressures (V.C., P.A., L.A. and portions of aortic tracing).

tion. It is wise to ligate and divide a fine branch that leaves the brachycephalic artery posteriorly about 1 cm above its point of emergence from the aorta. The left subclavian artery is cleared for a distance of about 3 cm above its point of origin. When the preparation of the vessels is complete, 30 mg per kg of Treburon[†] is given intravenously. Two Blalock clamps are placed on the aorta, one just distal to the left subclavian artery and the second about 2 inches distal to the first. The proximal (A) and distal cannula (A′) are then secured in place and the system filled with blood by releasing the proximal aortic clamp and opening a side arm until no air remains (Fig. 1). The distal aortic clamp is then released, and aortic flow is reestablished. The period of occlusion of the thoracic aorta lasts between 3.0 and 4.0 minutes, and during this period the brachycephalic artery still carries blood to the brain. After about 10 minutes the brachycephalic artery is then tied off at its origin, a Blalock clamp is placed just above its bifurcation, and cannula B inserted. Flow is reestablished in between 1.5 and 3.0 minutes, during which period blood flow to the brain is maintained only by the collaterals which reach it through the still patent left subclavian artery and the right internal mammary artery that comes up from below and enters above the point of brachycephalic occlusion. Finally, either the left subclavian artery cannula (S) is inserted or the left subclavian artery is simply occluded.

The proximal aortic cannulae (A′) conducts blood to the flowmeter (PT) from which it is distributed to descending aorta, brachycephalic and sometimes also the left subclavian artery. In this way the only vessels of significant size that receive blood from the left ventricle without having it first traverse the flowmeter are the coronary arteries. The method is, therefore, one which records cardiac output minus coronary flow. To obtain registration of total cardiac output, cannulation of both coronary arteries would also be required.

Aortic pressure, proximal to the opening of Cannula A, is obtained through a length of fine vinylite tubing that pierces the wall of the tubing connected to Cannula A and extends 3 or 4 mm beyond the cannula orifice. See C in Fig. 1. The desirability of this arrangement, recently pointed out by Paine *et al.*(8), is that it avoids errors imposed by the pressure drop of the cannula orifice itself. Vena cava, pulmonary artery, and left auricle pressures are also obtained when desired by means of appropriately placed catheters connected to electromanometers(9). Fig. 2A shows the registration of total aortic flow, vena cava, pulmonary artery, left auricle, and aortic pressures during and after partial aortic occlusion.

Summary. A technic of measuring total aortic flow has been presented which essentially reestablishes cardiovascular continuity, limits vascular dead space to less than 100 cc, and is accomplished by connections with intrathoracic arteries. The use of the Potter electro-turbinometer has eliminated the pressure buffer bottle, since it follows pulsatile flow accurately.

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